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VACUUM TEST ON A SAMPLE LAMBERTSON MAGNET

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Abstract

A three foot long test section of a Lambertson magnet has been baked under vacuum. A pressure of $\sim 1\times10^{-9}$ Torr (at 20°C) has been reached. The magnet can be let up to nitrogen at atmospheric pressure and be reconditioned with a bake at 80°C for a few hours. For magnets operating at elevated temperature, we measured the outgassing rate at 80°C, following a conditioning bake at 130°C. A pressure of 1.5×10^{-9} Torr was reached. In addition, the 17-foot long reverse injection Lambertson under construction has been similarly baked, with resulting pressures very similar to those of the test magnet.

Introduction

Lambertson magnets of the type used at Fermilab contain a stack of laminations in the beam vacuum envelope. The large surface area of the laminations makes it difficult in general to attain good vacuum. To study the effect of baking on the rate of outgassing in a practical Lambertson magnet we have assembled a 40-inch section of Lambertson laminations. The surface of the laminations was insulated with aluminum phosphate.

In order to remove the hydrogen introduced into the steel during the heat treatment during production (see appendix) we had the laminations degassed in vacuum (better than 10^{-5} Torr for at least an hour) at 800°C prior to stacking. The laminations were randomly placed in baskets during this bake.

After the 800°C bake the laminations were stacked under "clean conditions" (glove, but no clean room), hydraulically compressed between one inch thick stainless steel endplates and held together with welded steel straps. A thin stainless steel skin (1/32 in.) was welded to the endplates to form a vacuum tight enclosure. A 2 3/8 inch i.d. copper seal flange ("Conflat") was welded to each of the endplates, which had corresponding holes.

The size and shape of the laminations are shown in Fig. 1. The total weight was 600 pounds. The total "edge-on" surface area (exposed to vacuum) was 12,800 cm^2. There were 1,600 laminations of 0.0225 inch thickness with a total surface area of 1.09×10^6 cm^2.

The vacuum equipment is shown in Fig. 1. A mobile turbopump cart was available to evacuate the system through a 3/4 inch all metal valve. Two Main Ring-type ion pumps of 30 ℓ/s nominal pumping speed each were flanged to the endplates. Nude ion gauges were mounted inside short 1.5 inch sleeves at each end of the magnet.

Procedure

In order to learn the effect of various bake temperatures there were three bake cycles at nominally 200, 300 and 400°C. The first cycle had very uneven temperatures due to our inexperience in the use of heating tapes. The remaining cycles were quite uniform, as established through the use of 10 thermocouple gauges. These cycles are labeled on the vacuum pressure versus time graph (Fig. 2). At some time, probably before the 300°C bake, a small leak developed, limiting further improvements. When this leak was repaired, a bake to only 150°C brought the pressure down to 2.5×10^{-9} Torr with both ion pumps operating. The further history of the sample magnet is shown on Fig. 3 and includes several bakes and letting the system up to dry nitrogen and air. The data show that a recovery bake at 80°C is sufficient for magnets operated at 20°C, and that a bake at 130°C allows subsequent operation at 80°C with outgassing rates only slightly higher than those observed at 20°C (last part of Fig. 3).

The 17-foot reverse injection Lambertson was built from laminations treated in a way similar to those of the 3-foot sample magnet. Six Main Ring-type ion pumps (30 ℓ/s nominal) provided the pumping. Pressures on the three ion gauges (left, middle and right end) ranged from 1.1×10^{-9} Torr to 8×10^{-9} Torr after the last recovery bake (190°C). Therefore this large magnet confirmed the outgassing data obtained on the 3-foot model. More importantly, it proved that with this small amount of pumping one can maintain a full size Lambertson magnet at the required pressure level of below 10^{-8} Torr.

Conclusions

Lambertson magnets prepared in the following way:

-prebake laminations at 800°C in vacuum
-bake the assembled magnet at 400°C under vacuum
-let up to dry nitrogen for transport and/or repairs
-bake in the tunnel to 150°C

will be capable of pressures in the 10^{-9} Torr range. The outgassing rate of the above sample was 1.2×10^{-11} Torr ℓ/cm^2 sec if only the edge area is counted, or 1.4×10^{-13} Torr ℓ/cm^2 sec if all the surface area is counted. This latter number is consistent with published values, indicating that gas from the surface of the laminations reaches the pumps through the cracks between laminations, even though the conductance of the cracks is small compared to that of the pump channels.

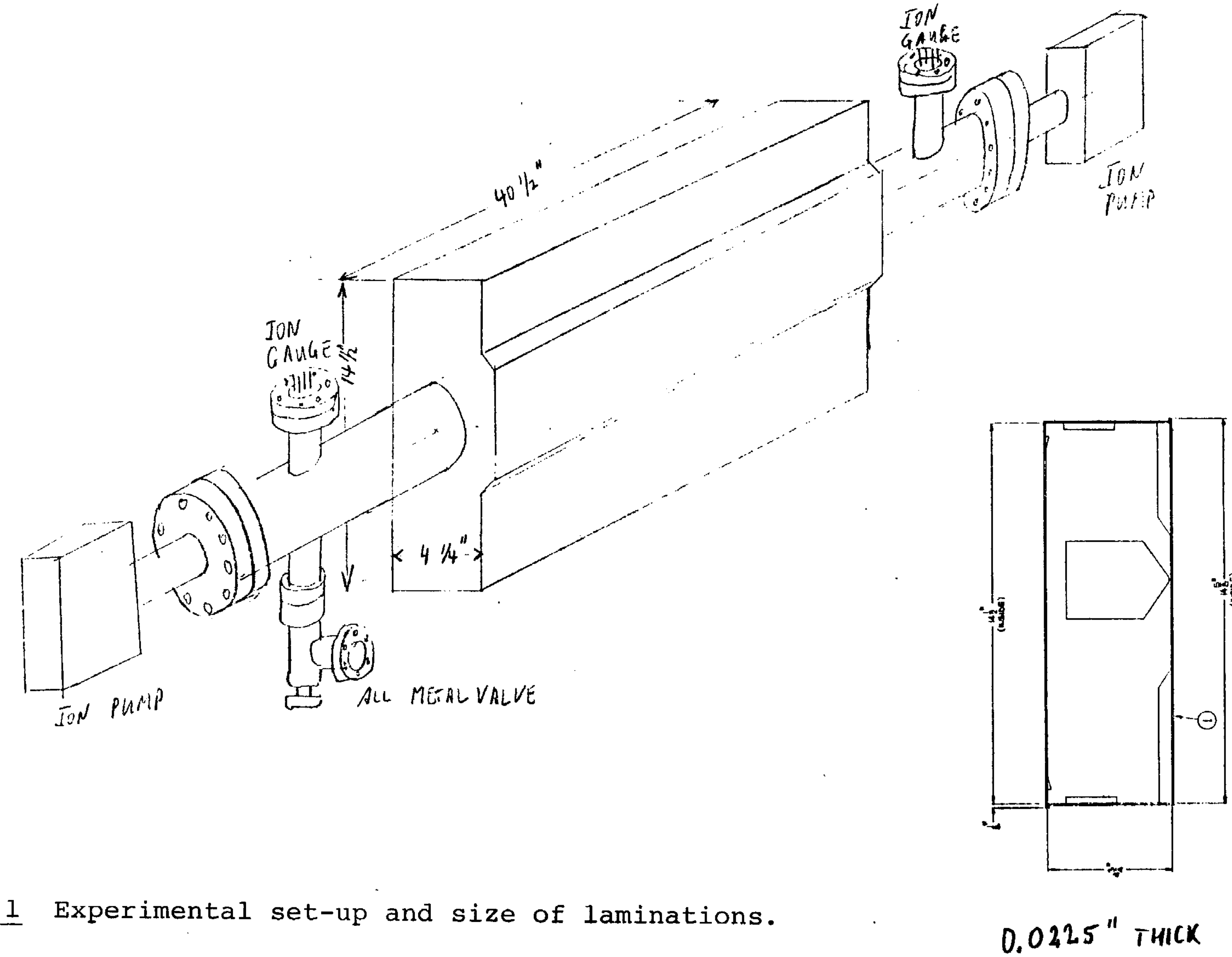


Figure 1 Experimental set-up and size of laminations.

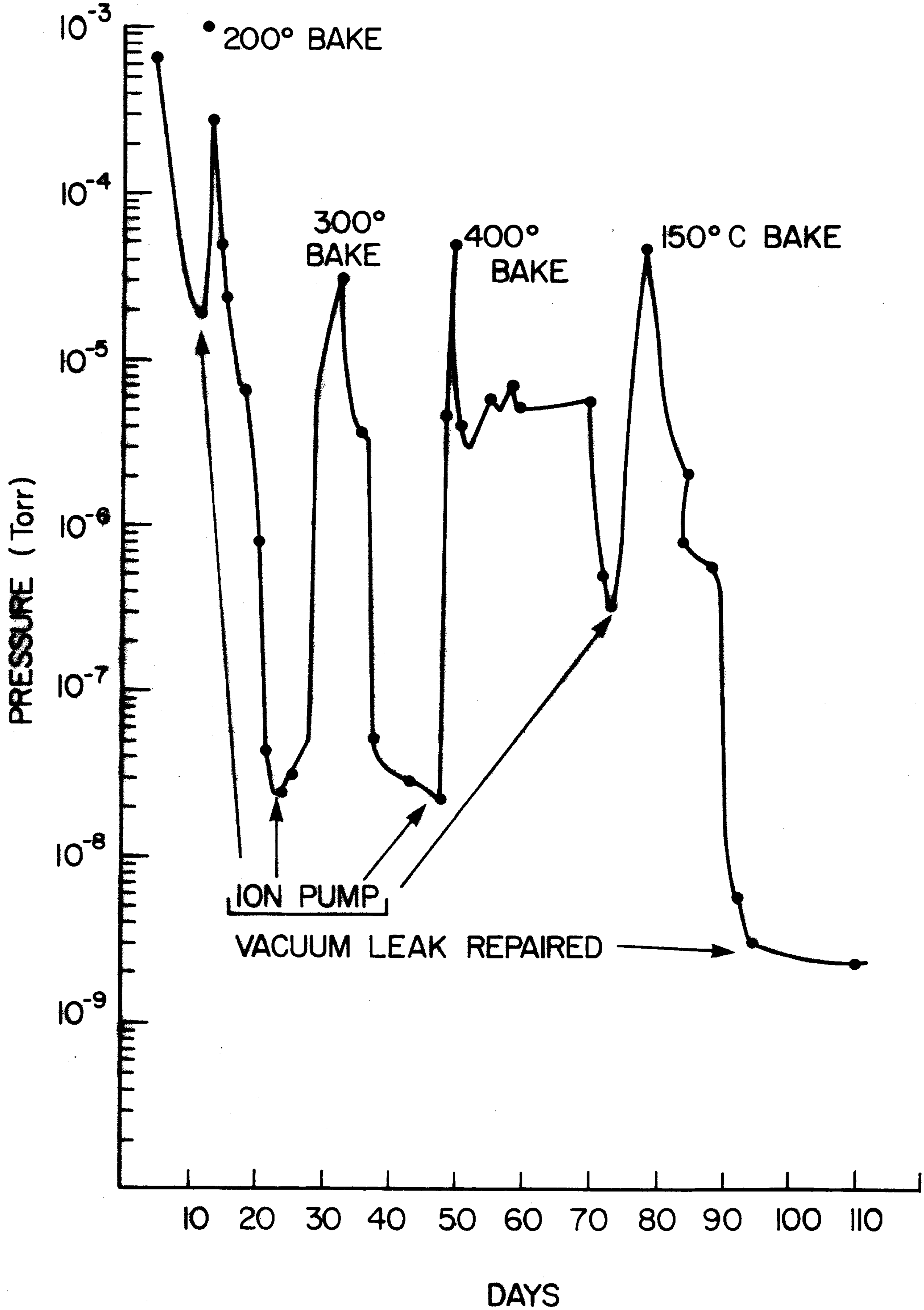
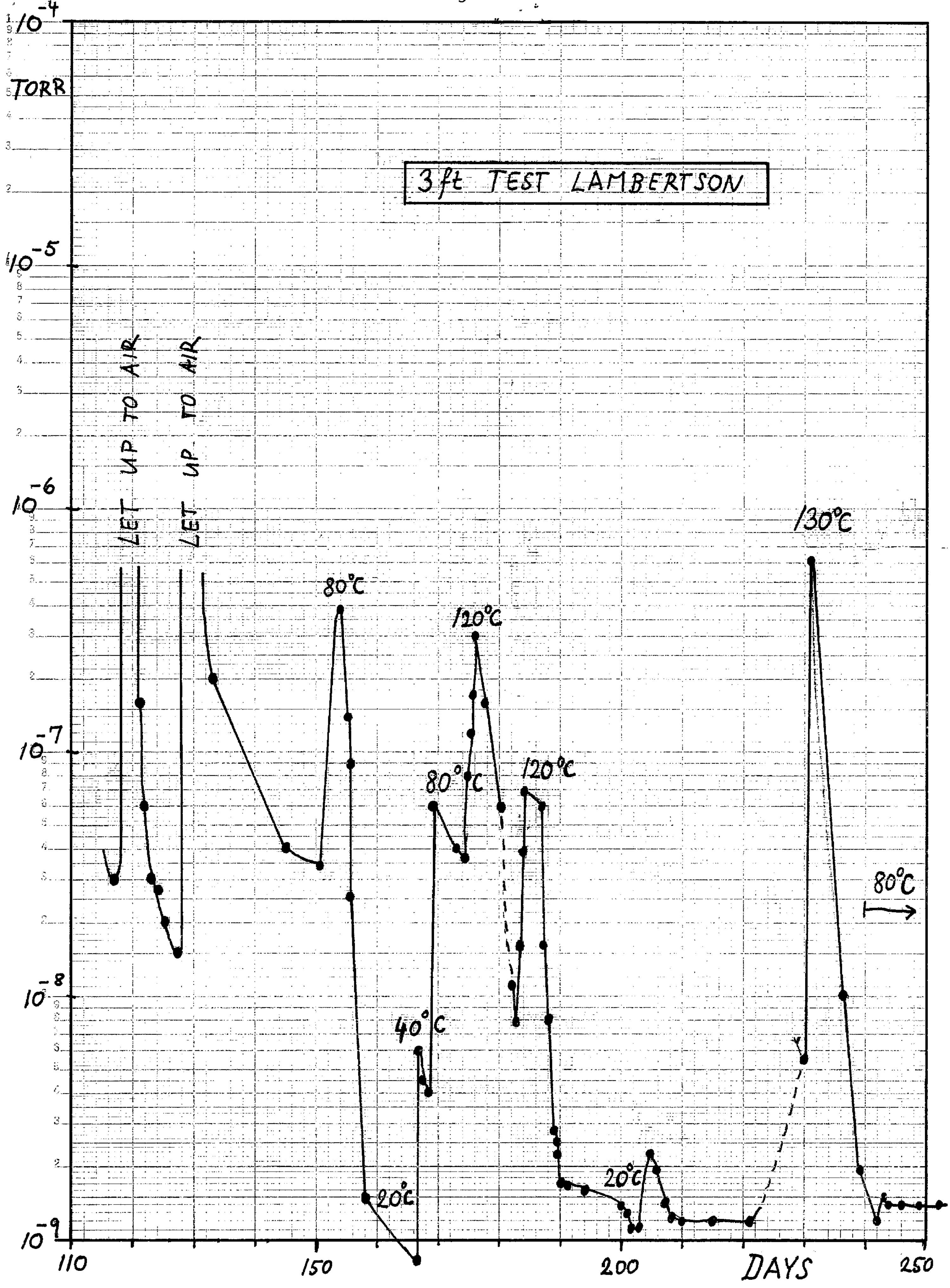


Fig. 2. Lambertson Magnet



3 ft TEST LAMBERTSON
TORR
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
LET UP TO AIR
LET UP TO AIR
80°C
120°C
80°C
120°C
40°C
20°C
20°C
130°C
80°C
110
150
200
250
DAYS

Fig. 3

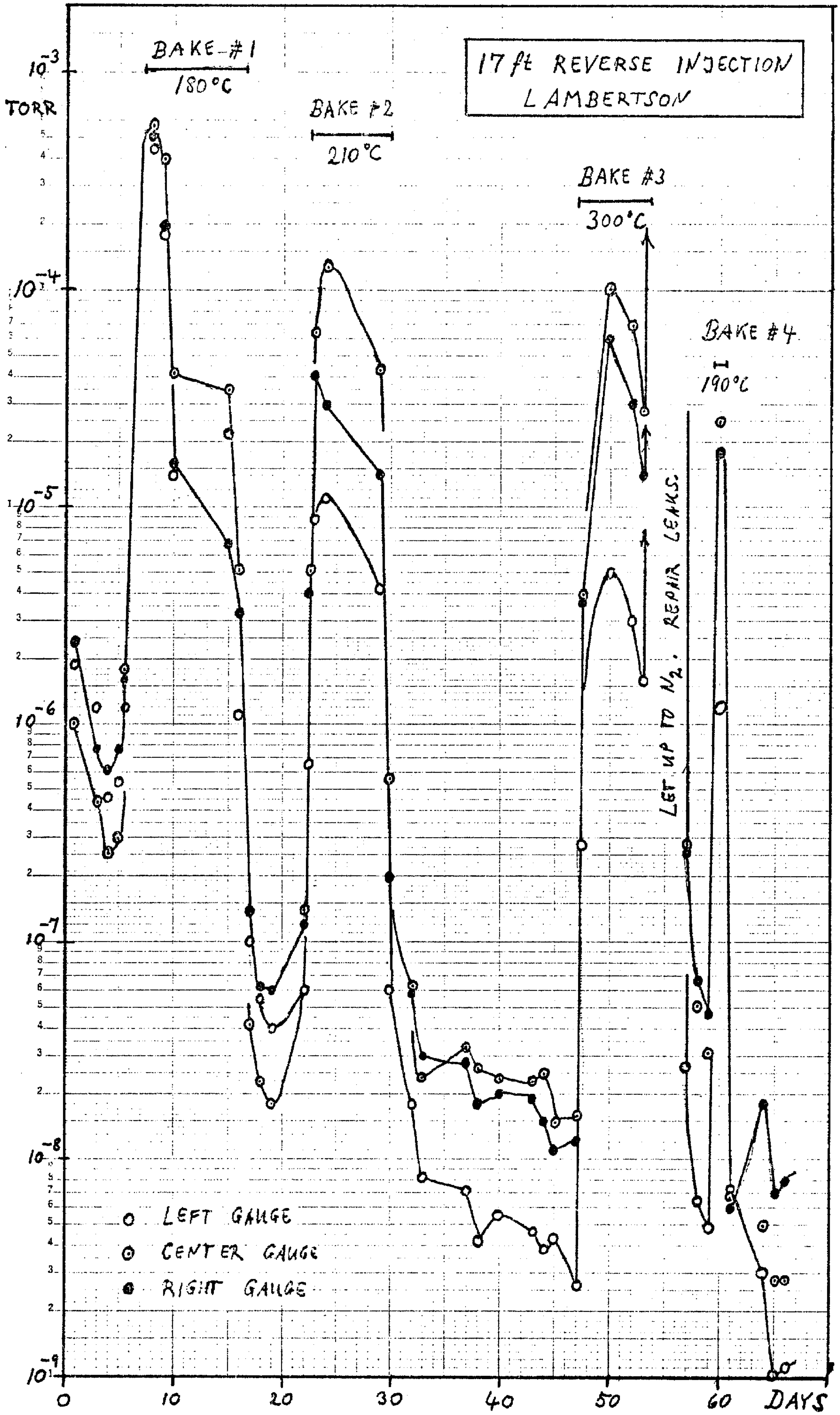
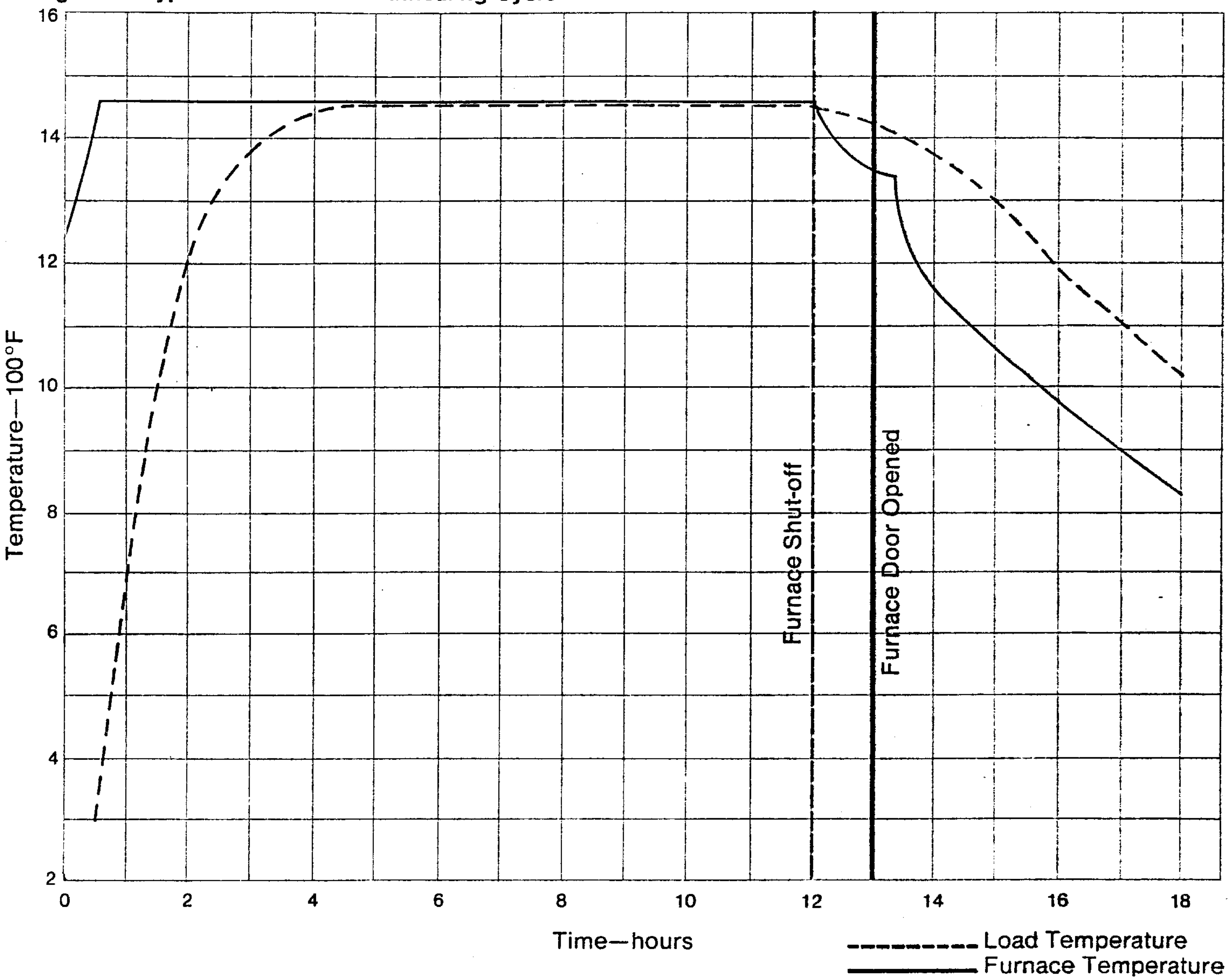

17 ft REVERSE INJECTION
LAMBERTSON
BAKE #1
180°C
BAKE #2
210°C
BAKE #3
300°C
BAKE #4
190°C
LET UP TO N2. REPAIR LEAKS.
TORR
10^-3
10^-4
10^-5
10^-6
10^-7
10^-8
10^-9
0
10
20
30
40
50
60
DAYS
LEFT GAUGE
CENTER GAUGE
RIGHT GAUGE

Fig. 4

APPENDIX

Silectron

Figure 2. Typical Stress Relief Annealing Cycle



through the upper temperature ranges may produce thermal strain and distortion, particularly on large cores. Below approximately 750°F, the cooling rate can be increased and the charge removed from the furnace and cooled in still air.

Continuous furnaces are generally more effective and efficient than batch type furnaces. The steel is uniformly exposed to the annealing atmosphere, and temperature differences in the steel are minimal.

A typical time-temperature relationship, satisfactory for most batch furnaces, is shown in Figure 2.

Annealing Atmospheres

A dry 80 percent nitrogen: 20 percent hydrogen atmosphere (0°F dew point maximum) is the recommended annealing atmosphere for most Silectron applications but pure, dry nitrogen is an acceptable alternative annealing atmosphere. Load furnaces should be purged with nitrogen before the annealing cycle is started. A nitrogen atmosphere should be maintained during cooling until the charge temperature is below 750°F to prevent minute changes in the steel chemistry.